

5        Claims

1.     A photonic crystal defect structure for a vertical cavity surface emitting laser:

        a plurality of holes arranged in a pattern; and

10       at least one missing hole defect in the pattern, a ratio of the hole diameter divided by the hole pitch being dependent upon the hole depth and set to produce single transverse mode operation.

2.     The structure of claim 1, wherein a radius of said missing hole defect  
15 is set to achieve single mode operation.

3.     The structure of claim 1, formed as part of a vertical cavity surface emitting laser, the laser including:

        a substrate;

20       a bottom distributed Bragg reflector;

        a top distributed Bragg reflector;

        an electrical current aperture;

        top and bottom electrodes; and

        a vertical cavity between said bottom and said top distributed Bragg  
25 reflectors containing an active region.

4.     The structure of claim 3, wherein said plurality of holes and said defect are finite depth holes formed in said top distributed Bragg reflector.

30       5.     The structure of claim 3, wherein said plurality of holes and are finite depth holes that extend through said vertical cavity and extend through at least a part of each of said top and bottom distributed Bragg reflectors.

5           6.     The structure of claim 3, wherein said plurality of holes and are  
infinite depth holes.

7.     The structure of claim 3, comprising a plurality of defects arranged  
in said pattern.

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8.     The structure of claim 7, wherein said pattern comprises a seven  
point defect pattern.

9.     The structure of claim 8, further comprises additional seven point  
15 defect patterns.

10.    The structure of claim 3, comprising a plurality of said patterns,  
wherein some of said patterns are different and some are matched to provide  
transverse optical coupling.

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11.    The structure of claim 10, wherein patterns are matched by having  
matched dimensions of said holes, pitch between holes, hole depth and defect  
radius.

25       12.    The structure of claim 3, wherein said electrical current aperture  
comprises an oxidized region in said vertical cavity.

13.    The structure of claim 3, wherein said electrical current aperture  
comprises an ion implanted region in said vertical cavity.

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14.    The structure of claim 3, wherein a refractive index difference within  
said vertical cavity is small enough to achieve single transverse mode operation.

5            15.    The laser of claim 3, wherein a radius of said missing hole defect is set to achieve single mode operation.

16.    The laser of claim 15, wherein dimensions are set such that the V-parameter of the laser is set such that  $V_{\text{eff}}$  is less than  $\sim 2.405$ , wherein  $V_{\text{eff}}$  is  
10 defined by:

$$V_{\text{eff}} = \frac{2\pi r}{\lambda} \sqrt{n_{\text{eff}}^2 - (n_{\text{eff}} - \gamma \Delta n)^2}$$

where  $\lambda$  is an operating wavelength,  $r$  is an equivalent defect radius,  $n_{\text{eff}}$  is the effective refractive index of the said vertical cavity without a photonic crystal  
15 hole pattern and defect structure present,  $\Delta n$  is the refractive index reduction introduced by the said pattern and said one or more defects, and  $\gamma$  is the depth dependence single transverse mode factor.

17.    The laser of claim 16, wherein  $\Delta n$  is set through optimization to an  
20 increased amount that maintains  $V_{\text{eff}}$  is less than  $\sim 2.405$ .

18    The laser of claim 17, wherein  $\Delta n$  is set to be greater than  $10^{-3}$ .

19.    The structure of claim 1, comprising a plurality of defects arranged  
25 in said pattern.

20.    A photonic crystal defect structure in a vertical cavity surface emitting laser, comprising:

- a substrate;
- 30 a bottom electrode electrically contacting said substrate;
- a bottom distributed Bragg reflector formed on an opposite side of said substrate from said bottom electrode;

5 a top distributed Bragg reflector;

a plurality of finite depth holes arranged in a pattern and a missing hole defect in the pattern, the pattern being formed in at least a portion of said top distributed Bragg reflector, the diameter, pitch and depth of the holes being defined by a depth dependence single transverse mode factor;

10 a vertical cavity including claddings that clad an active region, said vertical cavity being between said top and bottom distributed Bragg reflectors; and

a top electrode including an aperture larger than the pattern.

21. The structure of claim 20, comprising a plurality of defects arranged  
15 in said pattern.

22. The structure of claim 20, comprising a plurality of said patterns, wherein some of said patterns are different and some are matched to provide transverse optical coupling.

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